

The New AMD Athlon™ Processor

Enhancing the World's Most Powerful x86 Microprocessor

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Introduction: Building on a Reputation of Performance Excellence

Since its launch in 1999, the award-winning AMD Athlon™ processor family has outperformed other desktop x86 processors by delivering an optimal blend of microarchitectural performance and design for high-frequency operation. Industry-standard benchmarks¹ show that from demanding business-intensive applications to visual computing and Internet applications, the AMD Athlon processor family reigns supreme.

The new AMD Athlon processor, formally code-named the “Palomino” core, is designed to boost AMD’s x86 processor superiority through continued innovation in design and technology. Building on state-of-the-art AMD Athlon processor microarchitecture, the new AMD Athlon processor provides additional features and capabilities designed to enable outstanding future performance in the desktop space while allowing for increased expansion into the mobile, workstation and server x86 platform environments.

Design Enhancements: How Does the New AMD Athlon™ Processor Generate Industry-Leading Performance Across Different x86 Market Segments?

Processor performance on any given instruction set architecture is derived from two components: processor microarchitectural performance measured in IPC (Instructions Executed Per Clock) and processor frequency.

Simply stated: Processor Performance = IPC x Frequency

Other competitive x86 processor designs have made significant sacrifices to one of these two components to achieve gains in the other component. The new AMD Athlon processor, however, continues to exhibit the AMD Athlon processor family’s unique combination of microarchitectural performance and headroom for frequency advances, allowing it to outperform competitive products.

Along these lines, the new AMD Athlon processor has been improved through the following enhancements designed to deliver further increases in performance across different x86 market segments.

¹ The AMD Athlon processor’s industry-leading performance is supported by test results from a variety of integer, floating point, and 3D multimedia benchmarks. Visit www.amd.com for the latest benchmark data.

Low-Power Design and AMD PowerNow!™ technology: Achieving Synergy Between Extended Mobile Device Battery Life and the x86 Architecture's Highest-Performing Processor

The new mobile AMD Athlon™ 4 processor is the first processor available based on the new AMD Athlon processor core. Designed to enhance the productivity of mobile PC users, the mobile AMD Athlon 4 processor extends battery life while maintaining application performance. Two approaches were used to accomplish this goal: AMD PowerNow!™ technology and low-power design enhancements.

First, the addition of AMD PowerNow! technology within the mobile AMD Athlon 4 processor builds upon the original AMD PowerNow! technology implemented in the mobile AMD-K6®-2+ and mobile AMD-K6-III+ processors. This technology allows the processor to dynamically modify delivered performance—based on application requirements—to enhance system battery life. To accomplish this, original AMD PowerNow! technology-enabled dynamic software controls processor voltage and frequency based on application requirements. The mobile AMD Athlon 4 processor featuring AMD PowerNow! technology increases the flexibility and efficiency of this control. For a more in-depth discussion of this advanced power management capability, please reference the AMD PowerNow!™ technology brief at <http://www.amd.com/products/cpg/mobile/athlon/index.html>.

Second, the microarchitecture and its circuit implementation were redesigned from the current AMD Athlon processor to improve overall power consumption at a given speed grade. On the microarchitecture end, this meant undertaking an analysis of which logic functions could minimize unnecessary logic switching and avoid the power consumption that occurs each time a transistor switches from one state to another. For example, in a case where you have a circuit designed to receive values, perform a logical analysis of them, and then output values, there is a likelihood that some of the internal logic performing the analysis is switching much more often than the output values are varying. This is based on changes in the received input values. By intelligently observing which input changes would not necessitate an output value change, the design can prevent unnecessary switching by internal logic, and avoid extra power consumption.

Another design enhancement is an increased use of custom-designed logic. Custom-designed logic can increase frequency while reducing area, transistor count, and power consumption. On a lower level, the circuit implementation is optimized to reduce power

consumption by decreasing circuit drive strengths on certain logic paths. In essence, the lower the drive strength of a circuit, the smaller the size of transistors necessary to implement it, therefore the lower the amount of power consumed by the switching of those transistors. As a result, the new AMD Athlon processor consumes up to 20% less power when operated at the same frequency as the current AMD Athlon processor. This increases battery life, and provides the thermal power headroom necessary to scale frequency within the thermal limits of mobile platforms, thus maximizing overall performance.

Architectural Enhancements: Boosting Processing Power of the World's Most Advanced x86 Microarchitecture

The microarchitecture of the current AMD Athlon processor family is well designed for frequency scalability, and is not manipulated on the new AMD Athlon processor simply to generate further scalability at the expense of IPC and performance. The overall re-design is largely aimed at reducing maximum thermal power requirements, and targeting frequency gains when coupled with AMD's advanced processing technology. With an industry-leading processor architecture, low-power design, and frequency scalability, the new AMD Athlon processor is designed to continue to be the highest-performing x86 processor. While frequency is one factor in determining processor performance, it is not useful as a standalone measurement of performance, since processor microarchitectures can vary greatly. The new AMD Athlon processor is designed with the following enhancements to deliver industry-leading performance, enabling end-users to lead more productive lives.

3DNow!™ Professional Technology: Compatibility with More SIMD-Optimized Software Applications than any other x86 Processor in the World

Outside of improvements in processor architecture, it is possible to enhance the instruction set architecture to raise IPC and achieve more performance at a given frequency. The new AMD Athlon processor features 3DNow!™ Professional technology as an advancement in the evolution of 3DNow! technology introduced with the AMD-K6-2 processor in 1998, and enhanced 3DNow! technology introduced with the AMD Athlon processor in 1999. All 3DNow! technologies are aimed at achieving performance

optimization through the use of SIMD (Single Instruction Multiple Data) instruction extensions to the x86 instruction set architecture.

The new AMD Athlon processor with 3DNow! Professional technology adds 52 new instructions to the enhanced 3DNow! technology currently supported by the AMD Athlon processor. These new instructions, combined with the MMX™ integer additions included in enhanced 3DNow! technology, offer compatibility with Intel's SSE technology. Table 1 presents a breakout of the 3DNow! technology instruction set evolution.

Table 1: AMD processor support of SIMD instruction extensions to the x86 instruction set architecture

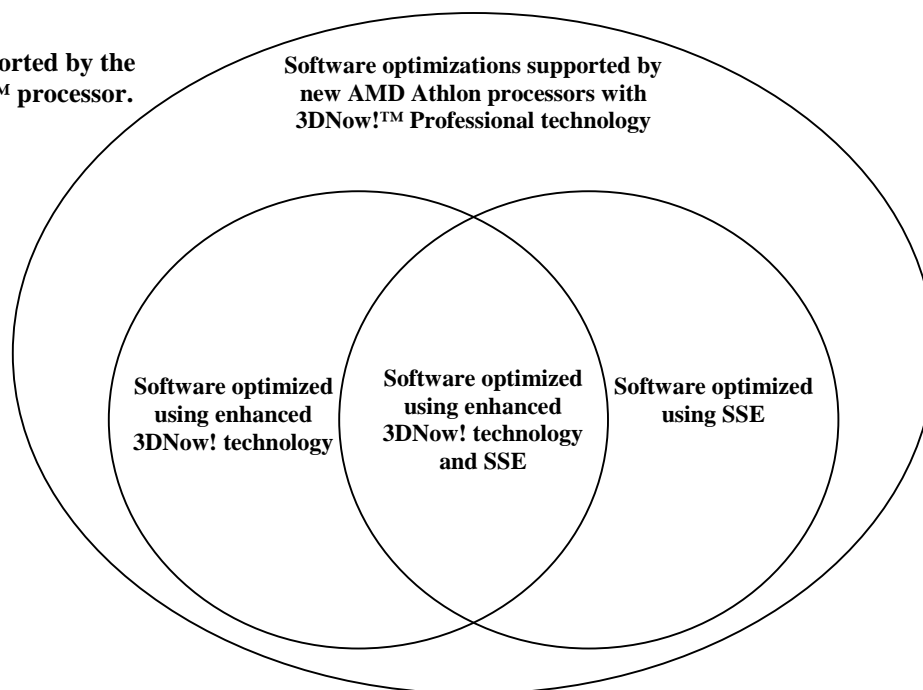
AMD Processor	AMD-K6®-2 Processor	AMD Athlon™ Processor	New AMD Athlon Processor
3DNow!™ technology version supported	3DNow! technology	Enhanced 3DNow! technology	3DNow! Professional technology
Description of instructions supported	Original 3DNow! technology extensions	3DNow! technology plus 19 MMX™ extensions (part of SSE) plus five DSP/communications extensions	Enhanced 3DNow! technology plus 52 SSE extensions (completing SSE support)

3DNow! technology and SSE are largely complementary architectural enhancements. By implementing them in a variety of ways, software developers are able to determine how they can utilize the advanced architectural capability enabled by SIMD instruction set extensions. Examples of applications most able to benefit from the use of these instruction set extensions include speech recognition, video encoding/decoding, and 3D graphics generation.

Many current software applications that are SIMD-optimized use different codepaths to benefit from 3DNow! technology or SSE, depending on the processor architecture on which these applications are executed. AMD processor architectures preceding the new AMD Athlon processor only supported 3DNow! or enhanced 3DNow! technology, which yielded the following three codepath scenarios for developers:

1. Software optimized exclusively for AMD processor architectures with 3DNow! technology use their 3DNow! technology-optimized codepath on AMD processors supporting 3DNow! technology.
2. Software optimized for both AMD processor architectures with 3DNow! technology, and other x86 industry processor architectures supporting SSE, use their 3DNow! technology-optimized codepath on AMD processors supporting 3DNow! technology.
3. Software optimized exclusively for other x86 industry processor architectures supporting SSE, use the non-optimized codepath on AMD processor architectures.

Figure 1: Software optimizations supported by the new AMD Athlon™ processor.



With the advent of 3DNow! Professional technology, the new AMD Athlon processor can seamlessly allow SIMD-optimized software in the third scenario above to recognize SSE support and run the optimized codepath for increased performance. The recognition of SSE support in 3DNow! Professional technology is performed automatically by PC software applications that use industry standard feature flags, provided in the CPUID instruction, to automatically recognize SSE support and run the optimized codepath. This means that with 3DNow! Professional technology's support for both 3DNow! and SSE technologies, the new AMD Athlon processor is able to take advantage of the performance gains offered by more SIMD-optimized software applications than any other x86 processor (see Figure 1).

Not only is the new AMD Athlon processor designed to benefit from existing software applications supporting 3DNow! and SSE technologies, but in the future, software developers will have the ability to utilize the strengths of both 3DNow! and SSE technologies when optimizing codepaths for AMD processor architectures which support 3DNow! Professional technology. The new AMD Athlon processor enables this advanced level of SIMD optimization by allowing 3DNow! and SSE instructions to be executed in the same codepath.

Data Prefetch: Optimized Use of High-Bandwidth DDR (Double Data Rate) Memory-Enabled Systems

Prefetching data from memory into the processor cache is a common technique used to enhance processor IPC and therefore processor performance. This reduces the average latency seen by the processor in accessing memory. In the past, the ability to hide memory latency has been supported through prefetch instructions introduced in 3DNow! and SSE technologies. This was helpful for software applications specifically optimized to take advantage of the capability, but offered no microarchitectural performance enhancement on non-optimized applications.

The new AMD Athlon processor combats this deficiency through the use of a data prefetch. This data prefetch mechanism observes memory accesses looking for regular access patterns (for example, those present in loop-based array data accesses), and speculatively fetches the cache line with the data into the processor's L2 cache in advance of the actual data access. The new AMD Athlon processor automatically optimizes performance on existing software that has not previously been optimized using the data prefetch instructions supported by 3DNow! Professional technology.

Benefits of the new AMD Athlon processor's data prefetching are observed more in high-end, data-intensive applications that access larger arrays of data. Performance also benefits by not occupying processor instruction execution bandwidth required by software prefetching instructions. The optimization is most effective when coupled with high-bandwidth system memory transfer capability, now available to the processor by platforms such as those optimized to support DDR memory.

TLB Enhancements: Increasing Performance on High-End, Data-Intensive Applications

The AMD Athlon family of processors features advanced, two-level TLB (Translation Look-aside Buffer) structures for both data and instruction address translation. The AMD Athlon processor's L1 ITLB (Instruction TLB) holds 24 entries, the L1 DTLB (Data TLB) holds 32 entries, and the L2 ITLB and DTLB each hold 256 entries. To further

enhance the IPC on high-end applications that access large amounts of data from memory, the new AMD Athlon processor incorporates three TLB microarchitectural optimizations:

1. The L1 DTLB increases from 32 to 40 entries
2. Both the L2 ITLB and L2 DTLB use an exclusive architecture
3. TLB entries can be speculatively reloaded

To reduce the incidence of TLB entry conflicts, the new AMD Athlon processor increases the size of the L1 DTLB from 32 to 40 entries and moves the two-level ITLB and DTLB to an exclusive architecture design. With an exclusive TLB architecture, the L1 can contain entries that are not duplicated in the L2 TLBs, enabling the combination of L2 TLB and L1 TLB sizes for a larger total available entry space on both the instruction and data TLBs. By reducing the number of conflicts caused by holding more TLB entries within the processor, performance increases on high-end, data-intensive applications that encounter instruction sequences that no longer have to wait for TLB entries to be reloaded during execution.

The third TLB enhancement introduced in the new AMD Athlon processor is the ability to enter data TLB misses into the TLB speculatively. On a TLB miss in previous AMD Athlon processors, the TLB entry would only be written into the TLB once the instruction has essentially finished executing. This resulted in subsequent instructions waiting for the completion of the first—if they were waiting for the same TLB miss—which can be observed to occur in some high-end software applications. The new AMD Athlon processor now allows TLB entries to be written speculatively before the first instruction is completed, while preserving proper instruction execution ordering which removes the serialization effect and results in improved performance.

The AMD Duron™ Processor

This white paper details the features and benefits specific to the new AMD Athlon processor. It should be noted, however, that with the exception of a smaller 64K L2 cache, the new AMD Duron™ processor featuring 3DNow! Professional technology includes the same set of microarchitectural enhancements as the new AMD Athlon processor.

Conclusion: Industry-Leading x86 Performance for the Mobile, Desktop, Workstation and Server Market Segments

By adding these enhancements to the new AMD Athlon processor...

- Low-power design—Enabling frequency headroom for the highest x86 processor performance available in the mobile PC market
- AMD PowerNow! technology support—Extending mobile PC battery life by up to 30% for increased productivity
- 3DNow! Professional technology support—Offering compatibility with the most SIMD-optimized PC software applications of any x86 processor
- Data prefetch—Increasing performance on high-end software applications using high-bandwidth system capability, especially with DDR memory
- TLB improvements—Increasing performance on high-end, data-intensive applications

...to the list of features already provided in the award-winning AMD Athlon processor...

- The most advanced, fully pipelined x86 superscalar floating point unit
- High-performance, full-speed, exclusive L2 cache
- Advanced 266MHz AMD Athlon processor system bus with ECC data transfer protection
- Stability of the Socket A infrastructure

...you have created the world's most powerful x86 processor, designed to meet the needs of tomorrow's most demanding applications. The new AMD Athlon processor provides industry-leading processing power for cutting-edge software applications including:

- **Multimedia / Digital Content Creation Applications**—photo and video editing, video encoding and decoding, image compression, soft DVD, MP3 encoding and decoding, etc.
- **High-end Desktop / Workstation Applications**—desktop publishing, speech recognition, CAD/CAM, 3D modeling and visualization, digital prototyping, etc.

Industry-leading performance across these and a host of other applications, combined with the ability to enhance the battery life of mobile device users and provide the reliability

and multiprocessing capability demanded by workstation and server users, has created the highest-performing x86 microprocessor solution in the world available across all major PC market segments.

AMD Overview

AMD is a global supplier of integrated circuits for the personal and networked computer and communications markets with manufacturing facilities in the United States, Europe, and Asia. AMD produces microprocessors, flash memory devices, and support circuitry for communications and networking applications. Founded in 1969 and based in Sunnyvale, California, AMD had revenues of \$4.6 billion in 2000. (NYSE: AMD).

Cautionary Statement

This white paper includes forward-looking statements that are made pursuant to the safe harbor provisions of the Private Securities Litigation Reform Act of 1995. Forward-looking statements are generally preceded by words such as “expects,” “plans,” “believes,” “anticipates,” or “intends.” Investors are cautioned that all forward-looking statements in this white paper involve risks and uncertainties that could cause actual results to differ from current expectations. Forward-looking statements in this white paper about the new AMD Athlon processor involve the risk that AMD may not be successful in developing an infrastructure or markets to support the new AMD Athlon processor; that third parties may not provide infrastructure solutions to support the new AMD Athlon processor; that the new AMD Athlon processor will not achieve customer and market acceptance; and that software applications will not be optimized for use with the new AMD Athlon processor. We urge investors to review in detail the risk and uncertainties in the company’s Securities and Exchange Commission filings, including the most recently filed Form-10K.

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